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FORECAST STUDY OF THE CONSUMPTION OF ELECTRICITY BY LOW VOLTAGE CUSTOMERS OF CAMEROON UNTIL 2035 AND THE IMPACT OF ENERGY EFFICIENCY ON THE SUPPLY AND DEMAND FOR ELECTRICITY.

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ABSTRACT

In this article, we perform quarterly estimate of the demand for electricity by customers of Cameroon Low Voltage using electricity as an energy source for the period starting in 1975 and ending in 2011. This approach aims at providing data on consumption of Low Voltage customer until 2035 and to assess the impact of energy efficiency on consumption. To carry out this prediction, we used linear and exponential models (Cobb-Douglas) whose parameters were estimated by EVIEWS 7.2 software. The exogenous variables used in this forecast are the socio-economic indicators namely the global GDP (GDPG), GDP per capita (per capita GDP), the number of households (H); the number of subscribers (S) and the population (PO). From this analysis it appears that the Cobb -Douglas models are better than linear models. The model including the overall gross domestic product (LGDPG), population (LP0) and the number of subscribers (LS) and autoregressive terms and mobile average was the best because it provided the highest coefficient of determination with 'Akaike (AIC) and Schwartz (SC) minimal criteria. We also note that the establishment of an energy efficiency policy would reduce the demand of electricity by about 10% and losses on the supply by about 3.2%.

***KEYWORDS:** Energy Efficiency, Forecasting, Linear Models, Exponential Models, Socio-Economic Indicators*

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Original Article

INTRODUCTION

The major concern of any electrical network operator is to guarantee and optimize the quality of service to its subscribers. This first requires an efficient network planning and effective monitoring of it. Due to the non-storable nature of electricity, its production and distribution in real time should be the priority of the operator at all times regardless of the conditions and hazards. Thus planners must "live with their expectations," in short, medium and long term to advise the government in the development of energy policies.

The strong economic growth in Cameroon for the last fifteen years is accompanied by increase in demand for power consumption. The electricity operator *ENEO (Energy ofCameroon)*, in charge of the management of the electricity system as a whole (production, transmission and distribution of electricity) has difficulty in answering this demand especially during peak hours and is not yet up to expectations of meeting all the electricity needs of the country both quantitatively and qualitatively. Plans have been established to strengthen the production capacity in the future but it is certain that the required deadlines are long and the implementation of these investment programs will certainly not allow making quick and effective solutions to the imbalance currently found between supply and demand of electricity.

The energy efficiency becomes henceforth nit only the key instrument to meet short and medium term to the growth of the increasing demand of consumers of electrical energy, but also acts as a long-term policy to reduce energy consumption and to limit investments for electricity production. The Energy efficiency means in other words the rational use of energy through the increase of the efficiency of its production, of its transport, of its distribution and its final consumption as well. It means that economic growth (which should not be compromised at any price) should be disconnected to energy growth. A unidirectional causal relationship from GDP to electricity consumption low voltages clients being observed, it can be established that an energy efficiency policy might not undermine the country's economic growth. Therefore the energy security of the country will be increased and substantial savings will be made in the import of fossil fuels whose prices enormously increase with the time. It should be noted that the cost of production of electricity by thermal power plants is more expensive than that produced by hydraulic power plants. Some thermal power being used for the management of the peak, a mastery of the electricity demand would reduce the high demand of energy during the peak. The establishment of an energy efficiency policy will also contribute to strengthening of the economic growth for, the manufacturing companies who today complain that their activity is constrained by the lack of electricity supply will be satisfied with the quality and the quantity of energy received. Finally, the pressure on the electrical system will be reduced. This will give more time for a rational planning of commissioning of new production capacity, enabling therefore significant savings in investment costs.

Our work is organized in five sections: after the introduction in section 1, Section 2 will present the literature review. Section 3 will be focused on the situation of electricity in Cameroon. Section 4 we will describe the data and the methodology used. Section 5 will be devoted to the presentation of results and the elaboration of an energy efficiency strategy in the field of electricity in Cameroon. A conclusion will complete our study.

LITERATURE REVIEW

The question of obtaining reliable forecasting methods of electricity consumption has been widely discussed by past research works. This is due to the increase in demand for electricity. Several studies have been done on electricity demand for domestic use in both developed and developing countries. The economic theory suggests that the electrical energy demand should be based on a number of factors such as:per capita income – the economic output –the supply – the costs of energy alternatives available to name few.These prospective methods include among others the use of econometric forecasting techniques, the artificial neural networks inter alia.

(Ozoh P. et al, 2014) use the modified Newton model to provide for the electricity consumption in Malaysia Sarawak University in Malaysia. The elaborating of this forecasting model is made from historical data of monthly electricity consumption from 2009 to 2012 at the University Malaysia Sarawak, Malaysia. From this forecast, they got a determination coefficient of 0.970 and a MAPE of 2.1%. They observed that the consumption decreases when students are on holiday (May - August) and increases during the high heat period because this heat emphasizes the use of fans and air conditioners to ventilate the air.

(Nadejda Victor et al, 2014) suggest a regression method for forecasting electricity consumption in non-OECD countries. The peculiarity of this work is the introduction of the variable “brightness” (night lights visible from space) as a proxy for electricity consumption over the population and past consumption. These brightness data allow an improvement in the quality of prediction of the electricity demand due to the availability in time and space thereof, contrary to the consumption of electricity which is not available and reliable for in many developing countries.

(MA Moradi et al, 2013) used the LEAP model (Long Range Alternative Energy Planning System) with a bottom-up approach in order to forecast electricity demand in the residential sector in Iran. This model is run under the Business-As-Usual scenario (BAU), with the inclusion of plans and active political past in the present momentum. The results obtained show that the demand for electricity in the residential sector in Iran has increased with an average annual growth rate of 1.93% and will reach 108.54 TWh in 2041.

(Mahirah Kamaludin, 2013) on the other side used the generalized moment method (GMM) to model the electricity consumption in 32 developing countries. He used as exogenous variables the GDP per capita, the price of oil (proxy) and the delayed consumption of electricity from 1999 to 2004. From this forecast, he observed that the delayed consumption variable had the most significant coefficient of the model and the coefficient of the "oil price variable" is negligible. He subsequently concluded that the introduction of the variable "price of electricity" will enable to obtain a better result.

(Bin C., et al, 2012) evaluated the residential electricity demand in China using single data at the household level (depending on the local price of electricity, household income) and a number of socioeconomic variables. They noted that this application substantially meets its own price. They also felt the elasticity of electricity through different heterogeneous groups of households (rich against poor, rural against urban). The results showed that the high-income group had a more elastic price than in low-income households while rural families are more sensitive in price elasticity than in urban families. They therefore concluded that these results have important policy implications for the designing of a rate increase block.

(Pernille Holtedahl et al, 2005) discussed residential electricity demand in Taiwan thanks to error correction model in terms of household income, the population growth, the price of electricity and the degree of urbanization as proxy for consumption. Following this analysis, they realized that the use of the error correction model enable to obtain the effects of income and short-term price smaller than those of the long term. They also found that the effects of cooling and degree-days have a positive impact on the short-term consumption. The use of urbanization helps to capture the economic characteristics of development and changes in stocks of electricity capital.

As the modeling of the electricity consumption of African country is concerned, (Oluremi Kayode et al, 2011) used an econometric model to estimate the demand for urban residential electricity in Nigeria. This model uses data from residential demand for electrical energy from 1975 to 2005. The econometric model deficiencies are highlighted and the dynamics of the modeling system is proposed as a complement to the econometric approach. They suggested that this hybrid approach including econometric techniques and dynamic of the system can lead to a better forecasting of electricity demand in developing countries.

(Adjamagbo et al, 2011) used four parametric models to predict the monthly consumption of the electric energy in Togo. Modeling data cover the period 2001 - 2005 and consist of power consumption readings, temperature and relative humidity. These data were bootstrapped in order to evaluate on a subsequent dataset the parameters of the various models. From this modeling, they found that the ARX models are more indicated for a better identification (reconstruction), with a mean square error of 105 kWh, thus 1% of the minimum consumption. The seasonal pattern was most effective for predicting with an error of 3.26 105 kWh.

The particularity of our work lies in the finding the best models to study and optimize them through significance tests of coefficients of Fischer and Student. We shall thereof conduct several tests to see if the noise obtained with different models is white and Gaussian or not. This will allow us to validate our various forecasting models.

Situation of the Electricity Sector in Cameroon

Electricity demand in Cameroon represents a small share of overall energy consumption (about 7%). Most rural areas are still not electrified, yet the balance between supply and electric power demand is very fragile, especially during the dry season when the hydro-electric capacity drops while the demand for electricity increases because of the high heat observed during this season. This requires the extensive use of air conditioners and refrigerators causing cuts and load shedding which greatly affects the country's economic development. Any additional electricity demand thus increases the pressure on the electrical system. In this respect, the analyzes based on past and current trends in one hand, in the absence of corrective actions taken by the public sector and / or implemented by the private sector on the other hand, consumption of Cameroon by 2035 will increase by about 90% compared to the consumption recorded in 2012.

Thus, it should be noted that the current demand (3710 GWh in 2012) already leads to an annual shortage of electric energy between the appeal of electric power and the provision, taking into consideration the loss rate at the level of production, of transmission and of distribution of electric energy abnormally high (the losses of the transport network are estimated at 6.3% while the technical and non-technical losses in the distribution represent 29.3% of the power provided by the transmission system).

To meet expected demand and in the absence of implementation of a proactive policy of reducing the electricity consumption growth rate in the country, it should be necessary to create by 2035 an additional power generation capacity of about 1,500 MW.

Production, Transmission and Distribution of Electricity

Production

The main source of electricity production in Cameroon is the hydroelectric system. This system however suffers from a serious underdevelopment. The hydroelectric production accounts for the bulk of domestic production, with more than 92% on average of national production of plants managed by ENEO Cameroon over the period 2005-2011.

Thermal power plants pose problems of reliability and efficiency. Many electric generators do not appear to be available in the dry season. It should be noted that the management of the peak requires additional production facilities like the thermal power plants. These plants use fossil fuels whose price continues to grow. The cost price per kilowatt provided by these plants is extremely high (about 50francscfaforhydroelectric power generation against 400 francs about cfa for plants production). The distribution of the production of electrical energy in Cameroon is presented in *Table 1*.

Table 1: Energy Production (in% of Total Production)

Year / Power Production	2005	2006	2007	2008	2009	2010	2011	Average Part
Hydro - RIS	89,00%	88,70%	85,20%	89,00%	84,80%	86,50%	86,30%	87,10%
Hydro- RIN	5,20%	5,10%	5,10%	4,90%	5,40%	5,40%	5,40%	5,20%
Hydro- (RIN+RIS)	94,20%	93,80%	90,40%	93,90%	90,20%	91,90%	91,70%	92,30%
Thermal- RIS	4,50%	4,80%	8,30%	4,40%	8,10%	6,30%	6,50%	6,10%
Thermal- RIN	2,9 %°	0,2%°		0,1 %°	0,1 %°			0,8 %° (per thousands)

Table 1: Contd.,

Total Thermal (RIN+RIS)	4,50%	4,80%	8,30%	4,40%	8,10%	6,30%	6,50%	6,10%
Total Hydro + ThermalRIS	93,50%	93,50%	93,50%	93,50%	92, 9%	92,80%	92,80%	93,20%
Total Hydro + Thermal RIN	5,20%	5,10%	5,10%	4,90%	5,50%	5,40%	5,40%	5,20%
TotalHydro + Thermal (RIN+RIS)	98,70%	98,60%	98,60%	98,40%	98,30%	98,20%	98,20%	98,40%
Total Isolated Thermalplants-RIS	0,15%	0,16%	0,17%	0,18%	0,16%	0,19%	0,21%	0,20%
Total isolated Thermal plants-RIE	0,73%	0,77%	0,74%	0,84%	0,94%	0,96%	1,05%	0,90%
Total isolated Thermal plants-RIN	0,41%	0,44%	0,38%	0,49%	0,55%	0,53%	0,53%	0,50%
Totalisolated thermal plants (RIN+RIS+RIE)	1,30%	1,40%	1,40%	1,60%	1,80%	1,80%	1,80%	1,60%
National overall	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

Source: AES-SONEL

Using the Peak at the Central

The calculations were carried out by considering the energy produced at each plant at the annual peak in the same plant. The duration of use, calculated for each plant unit enables to convert the energy generated by a power plant (MWh) in peak power (MW).

Examination of *Table 2* shows that the useful life span of hydroelectric plants is significantly higher than that of thermal power stations. The overall averages in hours of use are as followed:

- Hydroelectric power stations: 6148 h / year (with a higher average for the Edea plan with 6929 h / year).
- Thermal power stations connected to the network: 1931 h / year
- Hydroelectric power stations and thermal stations connected: 5397 h / year
- Isolated thermal power: 3910 h / year
- Overall production (plants managed by ENEO only): 5417 h / year

Note that the usage factor corresponds to the peak usage time related to the number of hours of the year, ie 8760 hours.

Table 2: Times calculated for using Peak (hours / year) - Thermal and Hydroelectric Power Plants Connected to an Isolated Network

Year/ Duration of use	2005	2006	2007	2008	2009	2010	2011	Average
Hydro - RIS	6 340	6 258	6 018	6 346	5 968	6 119	6 405	6 208
Hydro- RIN	5 117	5 222	5 229	5 538	5 274	5 447	5 314	5 306
TotalHydro-(RIN + RIS)		6 191	5 967	6 297	5 922	6 075	6 328	6 148
Thermal- RIS	1 226	1 323	2 388	1 474	2 296	2 288	2 582	1 939
Thermal- RIN	*	2	*	5	4	*	*	4
TotalThermal (RIN + RIS)	1 227	1 288	2 388	1 462	2 283	2 288	2 582	1 931
Total (Hydro + Thermal) RIS	5 277	5 261	5 304	5 485	5 240	5 494	5 801	5 409

Table 2: Contd.,								
Total (Hydro + Thermal) RIN	5 120	4 743	5 229	5 390	5 171	5 447	5 314	5 202
Total (Hydro+ Thermal) (RIS+RIN)	5 268	5 231	5 300	5 481	5 237	5 491	5 772	5 397
Total isolated Thermal plants - RIS	*	*	2 247	3 116	2 836	3 754	3 700	3 131
Total isolated Thermal plants - RIE	*	*	3 918	4 402	4 433	4 223	4 392	4 274
Total isolated Thermal plants - RIN	*	*	3 625	4 374	4 382	4 892	4 688	4 392
Total isolated Thermal plants (RIN + RIS+RIE)	*	*	3 586	4 353	4 327	4 467	4 377	4 222
National overall	5 268	5 231	5 266	5 458	5 218	5 469	5 739	5 379

Source: AES-SONEL data not shown *

- **Losses Nationwide**

The review of the annual reports of AES-SONEL allows to establish of development of technical losses and non-technical as well, combined for transport and the public sector (MV and LV distribution).The overall total average return of the networks over the period 2005 - 2011 is estimated at 78.4%. *Table 3* presents estimating technical and non-technical losses of electricity distribution network in Cameroon.

The state of the electric energy transport network is a major cause of inefficiency. Due to the weakness and aging of electric transport lines, the Yaounde area is subjected to significant voltage drops, to heavy losses and failures. Similar problems are observed on the long antenna 90 kV Bafoussam. As the equipment set for this production and transport will not change the circumstances, it is appropriate to consider very quickly the feasibility of new 225 kV lines to complete the future loop Edea-Yaounde-Kribi-Memve'ele. In the short term, only the actions geared towards reducing and compensating for reactive power transfer at the peak periods as well as load shedding and volunteers could relieve some of the forecasting constraints.

The distribution system is notoriously poor, both in urban areas than in rural areas. The technical and commercial losses remain high (30% overall and 12% for technical losses). For a significant improvement distribution side, it should take the usual measures such as the phase equilibrium, the choice of opening points, and the creation of new HV/MV, in addition to efforts to control demand.

Table 3: Estimation of Technical and Non-TechnicalLosses

%Losses	2005	2006	2007	2008	2009	2010	2011
Rates of distribution Technical Losses	12,00%	12,00%	12,00%	12,00%	12,00%	12,00%	12,00%
Rate of Non-Technical Lossdistribution	11,44%	10,40%	13,76%	14,17%	17,47%	17,13%	17,16%
OverallDistribution Losses	23,44%	22,40%	25,76%	26,17%	29,47%	29,13%	29,16%
Distribution yield	76,56%	77,60%	74,24%	73,83%	70,53%	70,87%	70,84%
Rate of technical losses (%)	10,8%	11,0%	11,7%	11,8%	12,5%	13,7%	13,8%
Rateof Non-Technical losses (commercial)	6,8%	6,3%	8,5%	8,8%	11,6%	11,9%	12,3%
Rate of total losses	17,5%	17,2%	20,2%	20,6%	24,2%	25,7%	26,1%
Networks performance	82,5%	82,8%	79,8%	79,4%	75,8%	74,3%	73,9%

Source: AES-SONEL 22/08/12 - File "Statistics Sales from 2005 to 2011 HV and MV + by BT Network"

Demand of Energy

Statistic of Annual Sales s of Electrical Energy in Cameroon

Table 4 presents a history of annual electric energy sales statistics of clients LV, MV and HV, as recorded by AES-SONEL, nationwide over the period 2005-2011. The table also shows the share of sales of each voltage level, as well as the

average rate of increase over the same period.The share of sales accounted for ALUCAM enterprise alone, was about 32% of global sales, including all voltage levels. This share has been in continuous decline over this historical period, going from over 42% in 2005 to nearly 31% in 2011. This decrease deficit can be justified by the electrical supply shortage, mainly in dry periods. This shortage is the result the significant decrease of hydro-electricity production in Cameroon. The annual volume of energy sales of SOCATRAL enterprise has remained stable while that of CIMENCAM enterprise has increased over the past three years. In overall, the total annual energy sales of HV has represented more than 39% of total sales of AES-SONEL in recent years, with a gradual decline registered from 44.2% in 2005 to 33.4% in 2011; this decline should be induced by the voluntary drop in the consumption of ALUCAM.

LV sales volume has been steadily growing, with a share increased from 32.9% to 40.9%. It is the same for MV sales volume, whose share rose from 22.9% to 25.7%. Overall, the sale to the Public Service (MV + LV) in 2011 represented roughly 67% of global sales and an average of 60% during the past six years.

Figure 1 shows the evolution of the energy sales by voltage range in Cameroon. From the overall records on recent history, the volume of sales to ALUCAM which is the largest HV consumer of the country till then had been stable during the first four years before recording a negative rate of change of -2.8 %. LV sales have evolved with a growth rate of 5.8% per year and MV sales at an average growth rate of 4% per year. Sales to the Public Sector (MV + LV) have evolved as well, with an average growth rate of over 5% over the last six years.

Table 4: Annual Sales (in MWh / year) by Voltage Level (Freehold Networks) at the National Scale

Year /Clients HV	2005	2006	2007	2008	2009	2010	2011	TCAM
ALUCAM	1380 189	1 379 379	1338 066	1399 791	1186 882	1214 698	1146 403	- 2,8%
SOCARAL	12 736	11 804	13 612	13 182	14 602	15 311	15 310	3,4%
CIMENCAM	45 776	47 533	50 570	47 958	66 422	63 750	64 367	6,8%
Overall HV	1438 700	1 438 716	1402 248	1460 932	1267 907	1293 759	1226 080	- 2,5%
Overall LV	1071 965	1 153 100	1171 414	1267 319	1266 740	1393 855	1500 131	5,8%
Overall MV	747 815	781 965	780 159	799 687	822 314	889 023	944 693	4,0%
Overall (HV+MV+ LV)	3258 480	3 373 781	3353821	3527 937	3356 960	3576 636	3670 904	2,1%

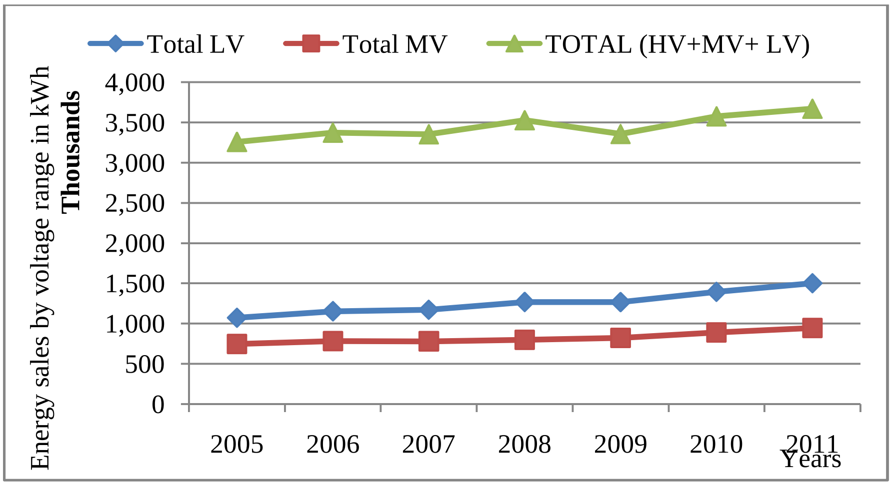


Figure 1: Evolution of Energy Sales by Voltage Range

In overall, total sales for the three voltage levels (MV + HV+ LV) has recorded an average growth rate of only 2.1%, due to the decline at the HV level in the last three years. Within that overall electricity consumption in the country, the industrial sector has occupied a prominent position, representing nearly 80% of this consumption with the aluminum sub – sector (48%) and the mining sub – sector (18%). However, due to regular power cuts, many companies have invested in electric generators to produce their electricity independently. The use of small electric generators is also widespread in residential and household levels. Self-production of power through the use of alternative energy sources such as biomass represents approximately 20% of electricity use (556 GWh), specifically from the sugar and cotton industries.An analysis of electricity consumption and foreseeable predictions has been carried out for each of the sectors (industry, commercial, residential buildings and households). This study was done on the basis of the trends observed over the last ten years, assuming that no voluntary proactive action would be undertaken to reduce the growth in demand in order to change or reduce these trends geared towards building a so-called a referential model.

- **Cameroon's Electrification Rate**

Figure 2 shows the rate of access to electricity and the poverty index by region in Cameroon. In 2007, the region that appeared to have the lowest access rate in electricity is the Far North, while the highest service rate was the southern region. The cities of Yaounde and Douala benefit from the most advantageous supply rate.

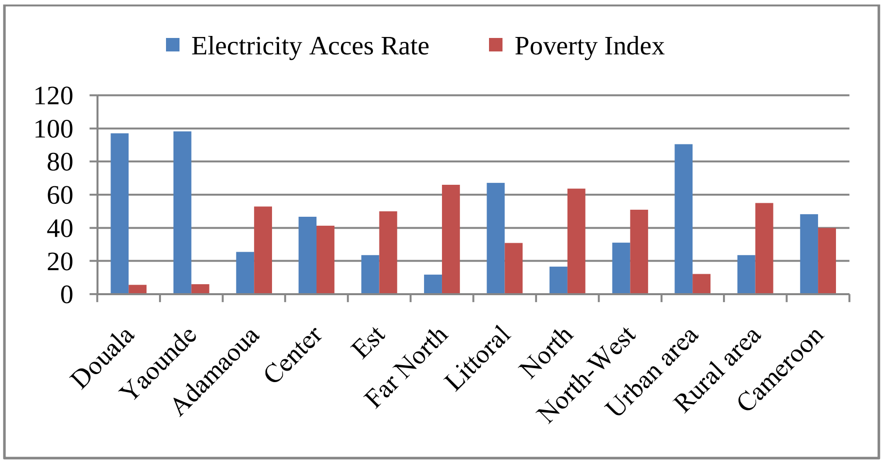


Figure 2: Rate of Access to Electricity and the Poverty Index by Region

The energy consumption of Cameroun accounted only 7.3% in 2012. One of the main reasons of this low ratio is the country's low electrification rate. This has increased over the period 2005-2011, going from 49.7% to 57%, thanks to government efforts to expand and densify the electrical network. This effort has had very positive effects in urban areas but poor results in rural areas where the majority of the population remains without access to the electricity network: the rural electrification rate stagnated at around 19% and has even slightly decreased since 2005.

METHODOLOGY

The Data

Evolution of Socio-Economic Indicators and of Consumption of Low Voltage

Quarterly data used in this study come from the AES-SONEL database; they spread out over the period 1975-2011. The data used for this study are:

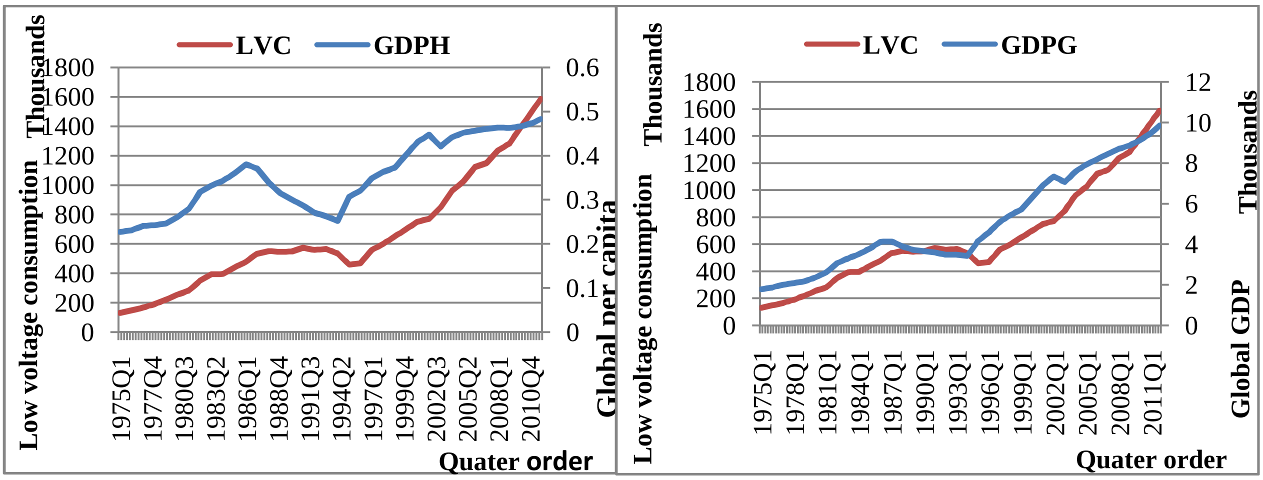
- The Gross Domestic Product (GDP) in real terms expressed in billions of CFA Francs; (GDPG)
- The GDP per capita (GDPH)
- Electricity consumption of low voltage customers expressed in gigawatt hours (GWh); (LVC) The population (PO)
- The number of households (H)
- The number of subscribers (S)

In addition, these data have been log transformed. The logs notations adopted are:

- LGDPG = logarithm of Global GDP;
- LGDPH = logarithm of GDP per capita;
- LLVC = logarithm of the electricity consumption.
- LS = logarithm of the number of subscribers
- LH = logarithm of the number of households
- LPO = logarithm of population

Evolution of Macroeconomic Indicators and of BT Consumers

Examination of the various graphs of *Figure 3* shows uniformity between the LVC growth and the various GDP. Coefficients of determination between this LV consumption and GDPH and GDPG are respectively 0.7874 and 0.9293. This enables us to confirm the positive influence that these GDP can yield on LVC. We also remark that consumption following the evolution of GDP for over all periods (the various GDP evolve from 1960 to 1986, decreases from 1987 to 1994 while the consumption of electricity weakly increases and takes off in 1995). The coefficient of determination of LVC and GDPG is the highest due to the fact that many companies use low voltage electricity. The various GDP thus have a positive influence on the LVC. We also remark that all variables grow over time; they are temporal or chronological data.



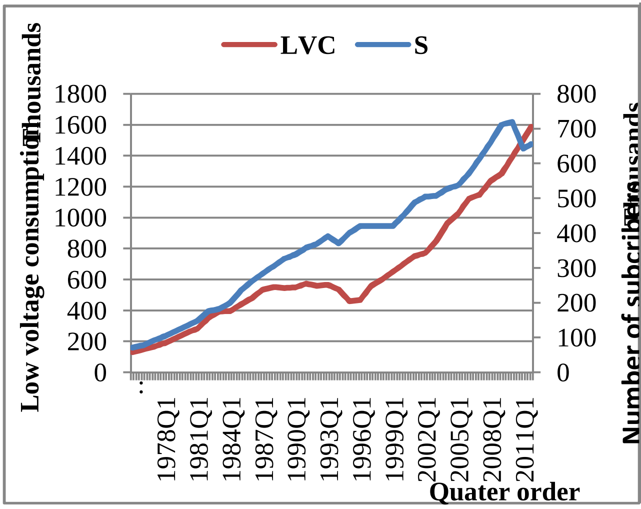
(a) **(b)**

Figure 3. Evolution of LVC curves and various macro-economic indicators (GDPH, GDPG).

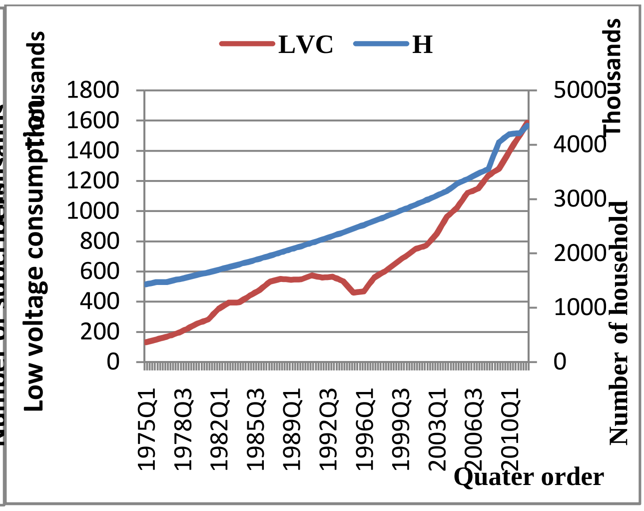
Evolution of Demographic Indicators and BT Consumption

Examination of the various graphs of *Figure 4* suggests a growth of all socio-demographic indicators for all periods on study. LV consumptions on their one follow this growth except from the period 1987 – 1995, period marked by the devaluation of the FCFA. This devaluation led to a decrease in the purchasing power of households and therefore a drastic drop their consumption of electricity. The coefficients of determination between consumption of electricity and the various demographic indicators namely population (PO), households (H) and subscribers (S) are respectively 0.9023; 0.9456 and 0.9133. These values allow us to confirm the positive influence that these indicators can bring on BT consumptions. Moreover, the coefficient of determination between LVC and the number of households is the highest. This is justified by the fact that the creation of a new household causes additional power consumption.

Figures 4 present the evolution of the quarterly values of the socio – economic indicators of Cameroon from 1975 to 2011.In abscises, 1975Q1 corresponds to the first quarter of the database (1st quarter 1975 = 1975Q1; 2nd quarter 1975 = 1975Q2; 1st quarter 1976 = 1975Q5…).



(a)



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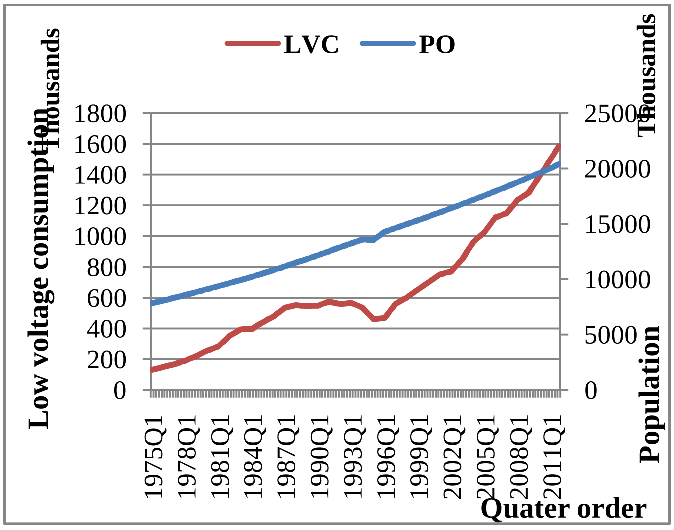


(c)

Figure 4. Evolution of LVC curves and various demographic indicators (population, households and subscribers).

In overall, one can observe a trend of growth in LV consumption with respectively those of population and real per capita income over the entire history, with few fluctuations. This can be explained by the significant share of the residential sector in LV consumption estimated at an average of about 71% in recent years.

- **Projections of Socio – Economic Data**

Table 5: Average Annual Rate of Increase of the Overall Population (TAAMP) in Cameroon Period *

Period	2010 – 2015	2015- 2020	2020 - 2025	2025 - 2030	2030 - 2035
TAAMP	2,47%	2,35%	2,3%	2,2%	2,1%

* rate according to hypotheses prospective of INS in 'Annuaire statistique du Cameroun – 2010' and compared to those of 'Cameroon: Vision 2035' – MINEPAT – June 2009 – Page 33

Table 6: Admitted Evolution of the Average High of Household in Cameroon Per Area *

	2010	2011	2012	2015	2020	2025	2030	2035
total Cameroon	4,68	4,67	4,67	4,53	4,41	4,20	4,06	3,91
Urban	4,45	4,45	4,45	4,41	4,37	4,18	4,00	3,85
rural	4,95	4,95	4,95	4,69	4,46	4,23	4,15	4,00

* Rate for the entire Cameron are results obtained from the rate admitted both for rural and urban areas

The projection of the average of GDPG and GDPH are presented on *table 7*.However, it should be noted that the rate of increase of the GDPH are estimated considering the hypotheses of the population growth in Cameroon. Then after, we shall predict the LVC taking into consideration the hypotheses of median scenario.

Table 7: Projected Evolution of the Average Annual Rate of Increase of GDPG and GDPH to Real Values

Horizon	2000-2010 Recorded	2010-2011	2011-2015	2015-2020	2020-2025	2025-2030	2030-2035	Moyenne 2011 – 2035
Top scenario								
AAGR of Real GDP	3,31%	4,0%	5,18%	5,94%	6,64%	7,84%	7,0%	6,05%
AAGR of Real GDP / capita	0,9%	1,47%	2,64%	3,51%	4,24%	5,52%	4,84%	3,68%
Midwayer scenario								
AAGR of Real GDP	3,31%	4,0%	5,18%	5,34%	6,04%	7,24%	6,44%	6,53%
AAGR of Real GDP / capita	0,9%	1,47%	2,64%	2,92%	3,66%	4,93%	4,25%	4,15%
Low scenario								
AAGR of Real GDP	3,31%	3,50%	3,50%	3,70%	3,90%	4,00%	3,95%	3,81%
AAGR of Real GDP/ capita	0,88%		1,03%	1,32%	1,56%	1,76%	1,81%	1,50%

Source of hypotheses: estimated forecasting from MINEPAT/DGEPIP/DAPE from 2011 to 2035

METHODOLOGY

- **Overview**

A time series or chronological series is a set of observations that stand out the important role played by the order in which they were collected.

The main models for the study of time series are:

• Autoregressive models ("Auto-Regressive"): They were introduced by *Yule (1927).*It considers a linear dependence of the process on its past:

AR(p) : $X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \cdots + \alpha_p X_{t-p} + u_t$

Where p∈ N*is the order of the process, $\alpha_1, \alpha_2, \ldots \alpha_p$ are real constants and(u_t) $_{t\epsilon Z}$ is a white noise.

- Moving Average Models: They were also introduced by *Slutsky (1927).*A moving average process is the sum of a white noise and its tardiness's:

MA(q) : $X_t = u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \cdots + \beta_p u_{t-q}$

Where qεN*β and $\beta_1, \beta_2, \ldots \beta_p$ are real constants.

•ARMA models ("Auto-Regressive Moving Average"). Developed by *Box &Jenkins (1970).*ARMA models are combinations of moving average and autoregressive models:

ARMA (p, q) :$X_t - \alpha_1 X_{t-1} - \alpha_2 X_{t-2} - \cdots - \alpha_p X_{t-p} = u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \cdots + \beta_p u_{t-q}$

•ARIMA (Auto Regressive Integrated Moving Average) and SARIMA (Seasonal Auto Regressive Integrated Moving Average) models were then developed in order to model a large number of actual phenomena that present trends and/ or seasonalities. ARMA models actually are applied to so-called differentiated series; a SARIMA process is an integrated ARMA process

The Models Selected for the Forecast

Linear regression is a statistical technique that helps to model the linear relationship between the explanatory variables (denoted Y_{it}) and a variable to be explained (denoted X_t).

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 Y_{1t} + \alpha_3 Y_{2t} + \cdots + \alpha_n Y_{nt} + u_t$$

where :

- $X_t$is the variable to be explained that in our article is the LV consumption
- $X_{t-1}$is the lagged value of LV consumption
- $Y_{it}$are the explanatory variables(global GDP, per capita GDP, population, number of subscribers and household)
- $\alpha_0, \alpha_1, \ldots \alpha_n$are the parameters to estimate of the model.
- $u_t$is the white noise defined by the relationship:

$u_t = \beta_1 u_{t-1} + \beta_2 u_{t-2} + \ldots + \beta_P u_{t-P} + \mathcal{E}_t$

The models used to modeling and forecasting quarterly of LV consumption in Cameroon considering socio-economic indicators are:

$$LVC_{t1} = \alpha_0 + \alpha_1 S + \alpha_2 H_t + \alpha_3 PO_t + \alpha_4 (GDPH)_t + \alpha_5 (GDPG)_t + u_t \quad (1)$$

$$LVC_{t2} = \alpha_0 + \alpha_1 S + \alpha_2 H_t + \alpha_3 PO_t + \alpha_4 (GDPH)_t + \alpha_5 (GDPG)_t \quad (2)$$

$$LVC_{t3} = \alpha_0 + \alpha_1 S_t + \alpha_2 H + \alpha_3 PO_t + \alpha_4 (GDPH)_t + \alpha_5 (GDPG)_t + u'_t \quad (3)$$

$$LVC_{t1\prime} = \mu_0 * \left(S_t^{\mu_1}\right)\left(M_t^{\mu_2}\right) * \left((PO)_t^{\mu_3}\right) * \left((GDPH)_t^{\mu_4}\right) * \left((GDPG)_t^{\mu_5}\right) \quad (4)$$

$$LVC_{t2\prime} = \mu_0 * \left(S_t^{\mu_1}\right)\left(H_t^{\mu_2}\right) * \left((PO)_t^{\mu_3}\right) * \left((GDPH)_t^{\mu_4}\right) * \left((GDPG)_t^{\mu_5}\right) * v_t \quad (5)$$

$$\left(\frac{\Delta LVC}{LVC}\right)_{t1\prime\prime} = \alpha_0 + \alpha_1\left(\frac{\Delta S}{S}\right)_t + \alpha_2\left(\frac{\Delta H}{H}\right)_t + \alpha_3\left(\frac{\Delta PO}{PO}\right)_t + \alpha_4\left(\frac{\Delta(GDPH)}{GDPH}\right)_t + \alpha_5\left(\frac{\Delta(GDPG)}{GDPG}\right)_t + \rho_t \quad (6)$$

$$\left(\frac{\Delta LVC}{LVC}\right)_{t2\prime\prime} = \alpha_0 + \alpha_1\left(\frac{\Delta S}{S}\right)_t + \alpha_2\left(\frac{\Delta H}{H}\right)_t + \alpha_3\left(\frac{\Delta PO}{PO}\right)_t + \rho'_t \quad (7)$$

where :

LCV_t: Low voltage consumption in quarter t

$((GDPH)_t$: Gross domestic product per capita (at constant prices) in quarter t

$((GDPG)_t$: Overall gross domestic product in quarter t

PO_t : Population in quarter t

$(S)_t$: Number of subscribers in quarter t

H_t: Number of households in quarter t

Where α_0 and $(\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7)$ are intercept and regression coefficients respectively. For handling serial correlation, we implement autoregressive in the error term of demand model. This usual method is expressed in (8). Here, autoregressive order two model is applied in the composed regression models. As options, models without and with autoregressive order one model are computed as well.

$$u_t = \beta_1 u_{t-1} + \beta_2 u_{t-2} + \ldots + \beta_P u_{t-P} + \varepsilon_t \quad (8)$$

$where u_t$, β_p, p and ε_t are respectively the terms error, the constant, the autoregressive order and the white noise.

RESULTS

Stationary Test: Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Tests

To determine the most appropriate model for our forecast, we have previously conducted Dickey-Fuller augmented (ADF) and Phillips-Perron (PP) tests on the variables used to determine their order of stationarity. At the threshold α = 1%, only variables LS, LPO, dS/S, dH/H, dPO/PO are Stationary. As other variables are not stationary, we have differentiated them to determine their stationarity order. Following these tests, we find that other variables are integrated on order 1 and 2. The results of these tests are given in *Table 8*. This leads us to introduce the ‘autoregressive’ and ‘moving average’ terms to the order 1 and 2, namely AR (1), AR (2), MA (1) and MA (2) in the model.

Table 8: Dickey-Fuller and Phillips-Perron Tests

Variables	Differentiation of Order 0		Differentiation of Order 1		Differentiation of Order 2		Results
	P-ValuePP.Test	P-Value ADF.Test	P-ValuePP.Test	P-Value ADF.Test	P-Value PP.Test	P-Value ADF.Test	
GDPH	1.0000	1.0000	0.1518	0.5228	0.0000	0.0000	d =2
GDPG	1.0000	1.0000	0.9994	0.9863	0.0000	0.0000	d =2
PO	1.0000	1.0000	0.0025	0.9479	*	*	d =1
H	1.0000	0.8368	0.0001	0.0539	*	*	d = 1
S	0.9461	0.9152	0.0000	0.0000	*	*	d =1
LVC	1.0000	1.0000	0.1063	0.0794	0.0000	0.0000	d =2
LGDPH	0.9948	0.9702	0.0005	0.0243	*	*	d =1
LGDPG	0.9896	0.9750	0.0012	0.0013	*	*	d =1

LPO	0.0000	0.0261	*	*	*	*	d = 0
LM	0.9861	0.9666	0.0000	0.0003	*	*	d = 1
LA	0.0002	0.0132	*	*	*	*	d =0
L LVC	1.0000	0.9997	0.1063	0.0794	0.0000	0.0000	d =2
	0.1518	0.5228	0.0000	0.0000	*	*	d=1
	0.9994	0.9863	0.0000	0.0000	*	*	d=1
	0.0025	0.9479	*	*	*	*	d=0
	0.0001	0.0539	*	*	*	*	d=0
	0.0000	0.0000	*	*	*	*	d=0
	0.1063	0.0794	0.0000	0.0000	*	*	d=1

Test of Significance of the Coefficients: Fischer and Student Tests

In order to determine the most appropriate variables for our study, we have previously written a linear equation where all variables intervened; we then analyzed their different coefficients thanks to Fischer (test of overall significance of coefficients) and Student tests (individual significance tests of the coefficients). The results are listed in the *Table 9 and 10*.

- **Test of the Overall Significance of the Coefficients (Fischer Test)**

The test of overall significance of the coefficients applied to the various models (Fischer test (F-stat)) at threshold α = 5% leads us to remark that there is significant overall coefficients for all models. We note that for both models 1 " and 2 " we have the lowest values of the coefficient of determination (0.818128 and 0.82006) and also the highest AIC and SC values. These two models permit to assess the rate of average growth of the quarterly electricity consumption of LV customers. This may be due to the fact that the average increase rate characterizes not sufficiently variables, for they can be sometimes increasing, sometimes decreasing depending the year. The results of this test for all the models are listed in *Table 9.*

- **Test of Significance of the Coefficients (Student's Test)**

The Student's test at the threshold α = 5%, shows that only the per capita GDP and GDPG variables are not significant in the linear models. However, the removal of these two variables reduces the coefficient of determination and increase AIC and SC. Therefore, these two variables are in fact significant for both models (models 1 and 2). Note that the quarterly modeling of LV customers is better with the introduction of the terms 'autoregressive' in the model. However the forecast is better without this term, since according to the graphs of the above *figure A*, it is clear that the best forecasting model is the one not involving the terms 'autoregressive'.

Table 9: Regression Coefficients for Quarterly Forecasting Models

Variables	*Model 1*		*Model2*		*Model 3*		*Model 1'*	*Model 2'*		*Model 1''*			*Model 2''*	
	Coef.	**Prob. (p-value)**	**Coef.**	**Prob .(p-value)**	**Coef.**	**Prob. (p-value)**	**Coef.**	**Prob. (p-value)**	**Coef.**	**Prob. (p-value)**	**Coef.**	**Prob. (p-value)**	**Coef.**	**Prob. (p-value)**
S	0.129474 (0.93159)	0.3532 0.13898*	*1.16407* *(4.883)*	*0.0000* *0.23838**	***0.1511*** ***(1.1122)***	***0.2680*** ***0.1359****	105340. (2.2698)	0.0247 46408.*	-69032. (-0.918)	0.3599 75147.*	0.14265 (1.0458)	0.2974 (0.1364)	0.161539 (1.31148)	0.1918 0.12317*
	-0.147236 (-4.06372)	0.0001 (0.0362)	*0.44496* *(6.875)*	*0.0000* *0.06471**	-0.1599 (-4.4404)	0.0000 0.0360*	2995124 (17.125)	0.0000 174889*	-33253. (-0.224)	0.8226 148047 *	-0.1516 (-4.273)	0.0000 0.0354*	-0.15350 (-4.4937)	0.0000 0.03416*
	0.081279 (2.49557)	0.0138 0.03256*	-0.1131 (-6.965)	0.0000 0.01624*	0.0772 (2.6743)	0.0084 0.0360*	1.1E+08 24945850 *	0.0000 0.6362	-171364 (-0.117)	0.9070 146438 2*	0.0803 (2.5133)	0.013110 .0319*	0.062487 (3.35907)	0.0010 0.01860*
	542.5721 (0.56546)	0.5727 959.519*	*-122.24* *(-0.248)*	*0.8040* *491.659**	915.542 (-1.0142)	0.3035 886.37*	1. E+08 (4.6282)	0.0000 24903271 *	-228816 (-1.633)	0.1046 140042 5*	609.026 (0.6453)	0.5197 943.66*		
	-31.25845 (-0.4699)	0.6391 66.5136*	88.9342(2.421)	0.0167 36.7240*	-63.373 (-1.0142)	0.3122 62.480*	-1.E+08 (-4.616)	0.0000 24892801 *	2490093 (1.773)	0.0784 140433 3	-37.38 (-0.572)	0.5678 65.282*		
Ar(1)	1.903677 (29.5673)	0.0000 0.06438*			1.84994 (31.920)	0.0000 0.0579*			0.98653(177.93)	0.0000 0.0055*	0.9271 (26.170)	0.0000 0.0354*	0.923440 (26.5388)	0.0000 0.03479*
Ar(2)	-0.903760 (-13.6462)	0.0000 0.06622*			-0.8456 (-14.208)	0.0000 0.0595*								
Ma(1)	0.047010 (0.47267)	0.6372 0.09945*			0.079965 (0.7936)	0.4288 0.1007*			1.04629(12.207)	0.0000 0.0857*				
Ma(2)	0.09652 (0.99187)	0.3230 0.09731*							0.2768 (3.223)	0.0016 0.0858*				
C	869539 (0.0288)	0.9770 3. E+08*	233041(1.170)	0.2438 199128.*	-383472. (-1.1232)	0.2633 341389*	-1.E+09 (-4.621)	0.0000 3.E+08*	-311931 (1.7731)	0.0784 207853 50*	8726.82(1.5328)	0.1276 5693.3*	9000.204 (1.7394)	0.0841 5174.26*

*() t-statistic, *adjs. standard error, _ the related variable is not significant*

The best modeling linear model is obtained by removing the parameter 'autoregressive' MA (2), it is thus the model 3 with acoefficient of determination 0.99985 AIC and SC criteria are respectively 19.66227 and 19.84619. Corresponding equation is:

$$LVC_{t3} = -0.1599\, H_t + 0.0772\ PO_t + 0.1511\, S_t + 915.542\ (GDPH)_t - 63.373\ (GDPG)_t + 0.079965\ MA(1)\ +1.84994\, AR(1)\ + -0.8456\, AR(2)\ + -383472.$$

Talking of the exponential model we note that it has the best forecasting model [Model 2 ' with a coefficient of determination 0.999729, AIC and SC criteria are respectively 20.29492 and 20.478. Corresponding equation is:

$$LVC_{t2'} = 31193 * (H_t^{-33253}) * (PO)_t^{-171364}) * (GDPG)_t^{228816}) * (GDPH)_t^{2490093}) * (S)_t^{-69032}) * \mathrm{AR}(1)^{0{,}98653}) * \mathrm{MA}(1)^{1{,}04629}) * \mathrm{MA}(2)^{0{,}2768})$$

Model 1 " and 2" are worse than linear and exponential models for, they have the lowest coefficients of determination. In addition the AIC and SC are higher in this models. The results of the various tests are listed in the *table 10.*

- **Tests on residue**

In order to verify the absence of autocorrelation of residues, we performed the Breusch-Godfrey (BG) test on all models for; in these models we have the lagged variable among the explanatory variables due to the presence of terms 'ARMA' in the various models. The residues are correlated at the threshold α = 5% if P-value <0.05. The analysis of the BG test to order 4 and at the threshold α = 5% shows that P-value <0.05 for all models except for models 2 and 3. In both models P-value = 0.586> 0, 05 and 0.5867> 0.05 respectively. The analysis of the residue of the square correlograms, the ARCH LM (Engle, 1982) and White (1980) tests applied to the various models lead to refute the hypothesis of the absence of heteroscedasticity of errors since for the threshold α = 5%, P-value <0.05 for all models except models 1; 1 " and 2 " or P-value > 0.05. Our residues been not homoscedastic, they are not white noise, except those of models 1, 1 " and 2 ". The

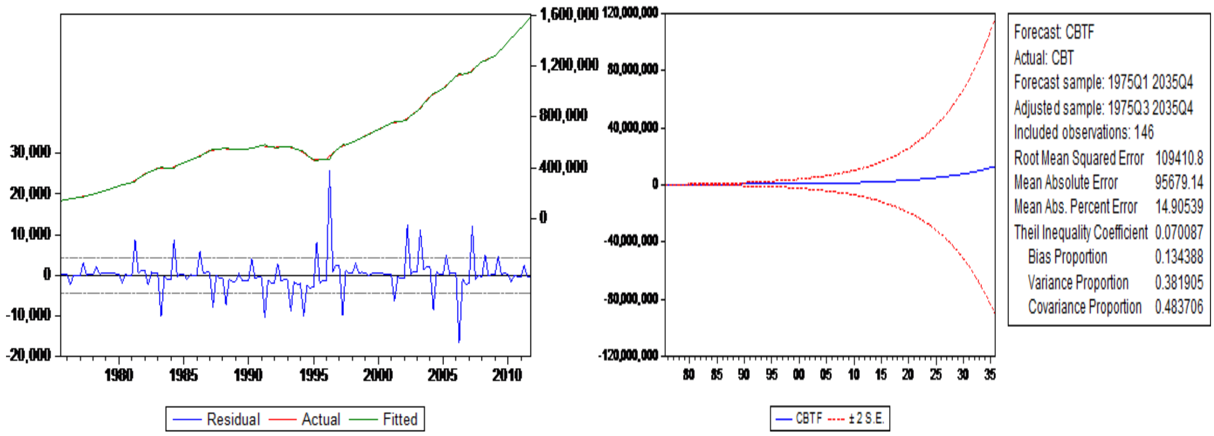
results of these tests are listed in *Table 10*.

Table 10: Statistical Regression for Quarterly Forecasting Models

	R^2	$R^{2'}$	SE Reg.	Prob. (F-Sta)	AIC	SC	F -Stat	White-test/ARCH		JB-test (p-value)	BG (LM)	
								ORS (p-value)	F-stat (p-value)		LM (p-value)	F- stat (p-value)
*Model*1	0.999860	0.999850	4440.080	0.0000	19.70077	19.90512	107648.8	14.80366 (0.0051)	18.03394 (0.0066)	912.06 (0.0000)	142.7824 (0.0000)	944.1144 (0.0000)
Model 2	0.969139	0.968052	65324.51	0.0000	25.05182	25.17333	891.8597	134.0295 (0.0000)	60.9205 (0.0000)	4.3570 (0.1131)	2.8977 (0.5751)	0.5867 (0.6751)
Model 3	0.999863	0.999855	4369.324	0.0000	19.66227	19.84619	125059.4	0.5990* (0.4389)*	0.5932 (0.4424)	805.8434 0.0000	4.6663 (0.4579)	0.924468 (0.4671)
Model 1’	0.966703	0.965530	67854.23	0.0000	25.12781	25.24932	616.9920	63.50208 (0.0000)	8.454627 (0.0000)	0.6900 (0.7081)	124.3198 (0.0000)	181.1235 (0.0000)
Model 2’	0.999744	0.999729	5996.217	0.0000	20.29492	20.47800	67318.95	8.632623* (0.0038)*	8.257494* (0.0041)*	3.3515 (0.1871)	67.80124 (0.0000)	28.67900 (0.0000)
Model 1’’	0.825654	0.818128	4401.345	0.000010	19.66397	19.80702	109.7108	0.638202* (0.4244)*	0.632181* (0.4279)*	910.958 (0.0000)	12.74903 (0.0126)	3.229094 (0.0145)
Modèle 2’’	0.7468	0.6905	4.0852	0.000001	5.8339	6.1481	13.27537	1.3075* (0.8601)*	0.2848* (0.8850)*	0.4052 (0.8165)	13.803 0.0079	4.3311 0.0093

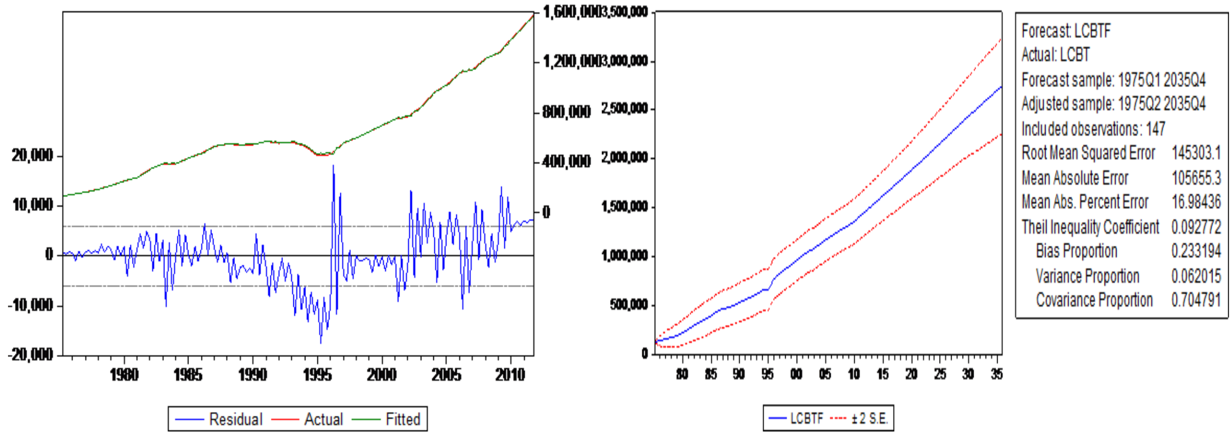
In order to determine if the white noise of models 1, 1’’ and 2” are Gaussian or not, we carried out Jarque-Bera (J-B) test. The hypothesis of obtaining a white Gaussian noise is true at the thresholdα= 5% if the Jarque-Bera statistic exceeds that read from the Chi-square table (JBstat<5.99) and the probability of Jarque-Bera’s statistical provided by Eviews is below the fixed threshold (P-value> 0.05).The analysis of this test allows us to accept the hypothesis of a Gaussian white noise for these three models (JBstat<5.99) and (P-value >0.05).The results of the various tests are listed in *Table10.*

Graphs illustrating the modeling and the forecast of LVC for the different models are shown in *Figures 5-6* that follow: in (A) residues are in blue color, observed series are in red color and estimated series are in green. In (B) planned the series are in blue color and precision interval at the 95%threshold are in red color.



(A) (B)

Figure 5:Model 3



(B)

Figure 6: Model 2'

Need for Implementation of Energy Efficiency Policy in the Electricity Sector in Cameroon

Introduction

The continuation of current electricity consumption trends in Cameroon will lead to a growing imbalance between supply and demand, which could be only partially compensated by planned investments in new production capacity. This compensation, could only be made provided that such investments are made in a timely manner and that the needed financial resources are mobilized. The implementation of a vigorous policy of energy efficiency in the electricity sector would reduce relatively in a short-term the pressure on the demand which appears to be absolutely necessary. Energy efficiency can be defined as a catalog of good practice devoted to achieve energy savings. It means to consume the electrical energy when necessary, that is to satisfy the electrical energy needs with less energy and the least possible loss. Beyond the expected impact in spreading the investments needed to provide the country with additional capacity to generate electrical energy, the design and development of such energy efficiency policy must however be seen as a basis for any future energy policy to limit the perpetual losses forward into new production tools. Even though these tools are based on the use of alternative energy sources using fossil fuels, they nevertheless require heavy investment and significant funding. The sustainability of the energy efficiency policy to set up should therefore be a basic criterion in its conceptual development.

It will be henceforth proper to reduce internal technical losses at the level of the electrical system i.e production, transmission and distribution. At the household level, substitution of incandescent lamps with energy-saving lamps is already a valuable step. However the most significant waste areas are undoubtedly constituted by the public buildings where State employees usually forget to turn off lights and air conditioners when exiting their offices. Furthermore, EE (Energy Efficiency) is now a major axis of intervention for electrical power companies. These companies have recourse to methods of energy planning, including consideration of the management of load curves, the promotion of effective components for the building and the use of standards or labelling of appliances. This strategy could allow introducing the technologies more appropriate to the constraints of the management of the electrical sector. In recent years, this policy finds new justifications in the fight against global warming through efforts to reduce greenhouse gas emissions in the electrical energy power generation industry.

Low Voltage electricity saving Potential in Cameroon

Savings Potential in the Tertiary Buildings Sector

- In the tertiary buildings sector, electricity saving measures primarily concerns first of all the air conditioning and lighting. The electricity savings potential in existing buildings can be divided into:
- - Short-term actions relating to the organization, the awareness and the reinforcement of the maintenance program as well.
- Medium-term actions aimed at improving on the performance of lighting and air conditioning.
- For new buildings, the development of a quality energy code of buildings whose purpose is to advance the quality of construction by imposing realistic specifications based on the state of the art and experience in buildings in Cameroon is an urgent necessity.
- Public buildings represent 37% of the energy consumption of the tertiary sector; other tertiary buildings represent the remaining 63%. The work on scenarios for energy efficiency has led to estimate the potential gain in electricity consumption in all of these buildings to 30% by 2035. This target is particularly sensitive for the public sector for which the lowering of the cost of electricity bills is an essential requirement. The reduction in electricity consumption there is a critical issue that is based primarily on the appointment and training of energy manager in charge of controlling the advocacy and the implementation of low cost measures. In addition, the energy audit is a prerequisite for the energy renovation of buildings, in order to introduce new efficient air conditioning, ventilation and lighting technologies.

Electrical Energy Saving’s Potentials in the Residential Sector

The residential sector is characterized by a profound change in the level of household electrical equipment thanks to development policies and the improvement of residents' income. Data on the breakdown of electricity use by households confirm the trend towards a larger quantity of electrical equipment used. The savings potential is both present in improving household equipment today (lighting, televisions, refrigerators) and also in the property that will be acquired in the coming years (housing, air conditioners, household equipment) as well. Housing construction has great potential of electricity savings. EE measures must support the development of air-conditioning units, i.e these measures should focus on to construction rules (insolation, solar protection) and the performance of air conditioners (energy performance standards) too.

In the residential sector, the largest potential savings estimated at 30% relies on rules, regulations and norms. All the appliances used by households must gear the definition of minimum energy performance either in a pure Cameroonian context, or by reference to what is done in other countries, be it developed or developing. Reference may be made for example to the global program ‘lighten’ as regarding lighting, but also can build a specific approach with regard to other equipment such as air conditioning. Anyway, consultations with stakeholders from the private sector as well as the establishment of accompanying measures to ensure the effective implementation of these regulations are necessary.

Development of an energy efficiency strategy in the field of electricity in Cameroon

Impact of Energy Efficiency on the of Low Voltage Consumption Customers

For this study, we have developed two electric energy consumption scenarii in order to define an energy efficiency

policy in Cameroon. These scenarii are based on various levels of ambition for public action to encourage or require increased efficiency in the use of electricity. Based on two different visions these two scenarii are called, 'ambitious scenario' and 'Standard scenario' for the first and the second respectively

Standard MDE Scenario: This scenario describes the possible savings potential through a simple and low-cost program to achieve the most readily available energy savings;

MDE Ambitious Scenario: This scenario shows the results that can be obtained through a coherent and proactive program of multiple public actions in order to stimulate or to enforce the implementation of all measures that are technically and economically possible, i.e those whose return time is considered reasonable, depending on the sectors concerned.

Table 11: Comparison of Baseline Scenario to Energy Efficiency Scenarii

Scenarii	2012	2035	% Savings in 2035	Amount of annual savings in 2035	Annual value of savings for consumers
	GWh	GWh	%	GWh	billion FCFA
Reference	3 710	7 040	-	-	-
MDE Standard	3 710	5 630	10	1 410	180
MDE Ambitious	3 710	4 920	30	2 120	271

These scenarii provided the framework for selecting the most appropriate measures for each sector according to their potential impact, their greater or lesser ease of implementation (short or long term) and their cost, for an overall goal of reducing energy consumption by30% by2035. *Table11* presents the results of these two scenarii by 2035 compared to the reference scenario.The Action Plan developed for each of the sectors of electricity consumption as well as for the supply sector (production, transmission and distribution of electricity) has varied types of measures that are listed in *Table 12.* In *table 11* we have colored in red the percentages of measures for evaluating energy savings by Low Voltage customer. *Figures 7, 8 and 9* show the evolution of the forecast curve of low voltage power consumption customer's indifferent scenarii: the blue curve represents the evolution of the observed electricity consumption from 1975 to 2011. The red curve represents the forecast consumption of electricity from 2012 to 2035in the reference scenario. The green curve represents the prediction curve of low voltage consumption customer in the standard MDE scenario described above. The purple curve represents the prediction curve in the ambitious MDE scenario. We have evaluated the energy saving about 10percent of the initial consumption per year.

Table 12: Electricity Savings and Costs of Energy Efficiency Measures

Categories of Measures	Energy Saving		
	In% of the Annual ElectricityConsumption of the Country *	GWh / Year	Enk €/Year
Energy Efficiency Act	N/A		-
Establishment of PNEE entity	N/A		-
Implementation and standards labeling procedure	2,0%	10,7	675
Implementation and auditors and energy managers certification procedure	0,5%	2,7	225
Education and training programs	0,5%	2,7	135
resource center	0,8%	4,3	180

Support for industrial energy audits	9%	48,4	1 575
Support for cogeneration	12%	64,5	3 075
Audit of buildings	1,5%	8,0	1035
Managers of public buildings	1,0%	5,5	704
Building codes **	2,0%	10,8	1375
Large public campaigns	1,9%	10,2	1305
Program to replace incandescent lamps	1,5 %	8,0	1035
Reduction of losses	3,2%	17,2	2200
Overall		193	22 515

Source: National Policy, Strategy and Plan of Action for Energy Efficiency in Cameroon in the electricity sector, November 2013

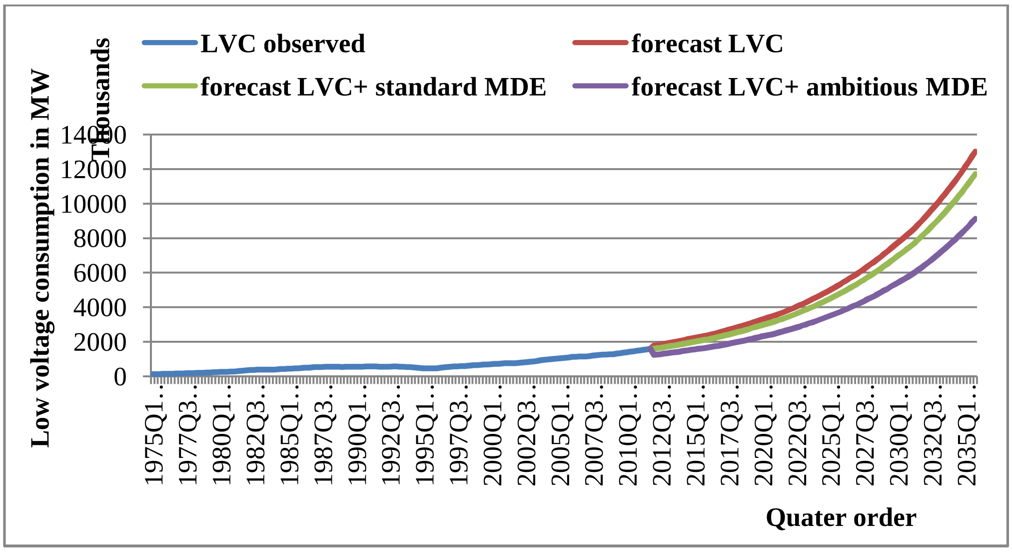


Figure 7: Evolution of LVC and Forecast in various scenarii including MDE

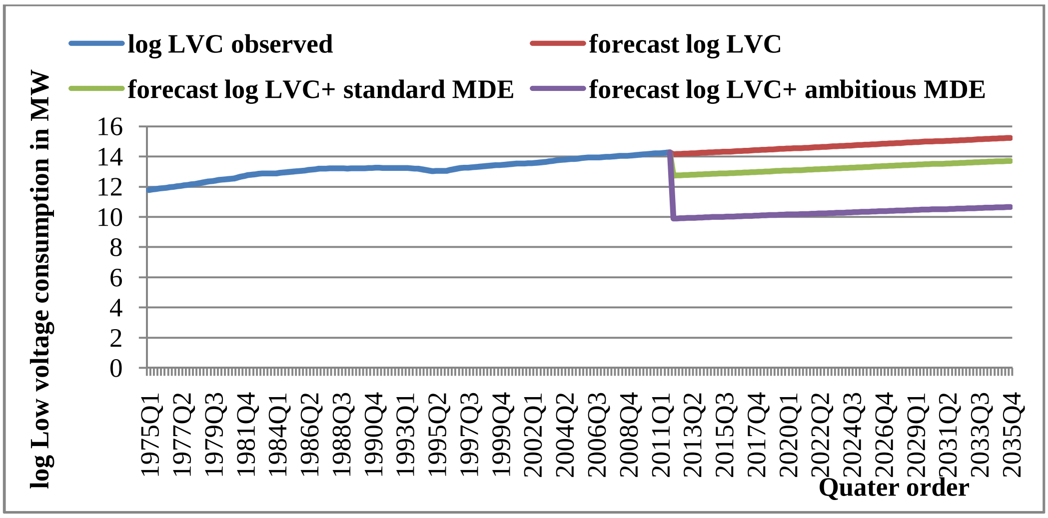


Figure 8: Evolution of LLVC and Forecast in various scenarii including MDE

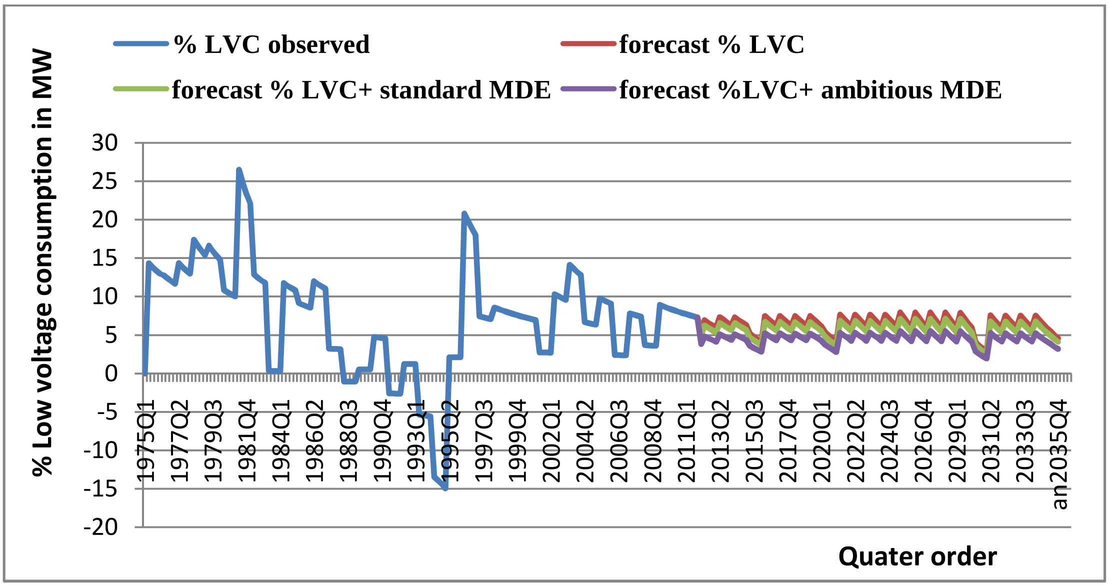


Figure 9: Evolution of LVC percentages and Forecast in various scenarii including MDE.

According to various studies it appears that by 2035, Low Voltage customers of Cameroon will consume approximately 4,124,448.19 kilowatts. The implementation of a policy of mastering of electricity demand would save 10% of the said demand and would reduce it to about 3,712,003.37 kilowatts in the standard MDE scenario. A saving of 30% could be achieved in ambitious scenario and reduce electricity demand to about 3299558, 551kW.

CONCLUSIONS

This study was aimed at analyzing the energy efficiency to allow Cameroon to ensure a sustainable economic growth, which remains dependent on energy. To carry out this study, we have adopted technico-economic methods for modeling and forecasting of our data. After having performed the various tests required by this type of data, we have selected the exponential model for; it was the most suitable for our forecast.The implementation of an energy efficiency policy is possible. It is the best option for developing countries such as Cameroon in order to reduce the imbalance between supply and demand for electricity.

However, this will only be possible if the government and the company that produces, transmits and distributes electric energy work together. This requires a broad public awareness campaigns on the merits of it, subsidies for low-energy appliances, the reduction of billing during off hours and its increase during hours peaks.... The theme of energy efficiency, particularly in the building sector has a real development opportunity in Cameroon. Energy efficiency is here synonymous with development as it will help to reduce the dependence on oil, to eliminate subsidies in electricity and fuel prices and thus to allocate more resources to priority budgets such as health, education or agriculture.

The behavior of the time series has allowed to alternate ARMA and SARIMA models. The adjustment of functions is reliable with good margins of error. We have obtained functions which strongly adhere to the intermediate scenario assumptions. We note that energy efficiency could reduce the energy demand of LV consumers in Cameroon in the short term, and also the monthly peak at 20h. Remember that the management of the peak requires the use of thermal plants which not only dramatically increase the cost of production but also produce harmful greenhouse gases harmful for humans and the environment. Presently, there is a massive importation of second hand appliances that are relatively large

electricity consumers'. In short, we must promote energy efficiency by disseminating efficiency standards at the level of enterprises and public buildings. The implementation of the ambitious MDE scenario would benefit to high extend since it will reduce the demand as well as the electricity bills of LV customers.

REFERENCES

1. **A.Al-Shehri,** '*A Simple Forecasting Model for Industrial Electric Energy Consumption*', International Journal of Energy Research, Vol. 24, N°8, pp. 719 – 726, 2000.
2. **Abosedra, S., et al., 2009.** Electricity consumption and economic growth, the case
3. of Lebanon. Applied Energy 86, 429–432.
4. **Agence de Régulation du Secteur de l'Electricité (2012):** rapport d'activités 1er trimestre 2012.
5. **Andrews, Donald W. K. (1993**). "Tests for Parameter Instability and Structural Change with Unknown Change Point," Econometrica, 61(4), 821–856.
6. **A.Pardo, V. Meneu and E. Valor (2012)**, "Temperature and Seasonality Influences on Spanish Electricity Load," Energy Economics, Vol. 24, pp. 55-70, 2002.
7. **Apergis, N., Payne, J.E., 2011.** The renewable energy consumption-growth nexus in
8. Central American. Applied Energy 88, 343–347.
9. **B. E. Psiloglou, C. Giannakopoulos, S. Majithia, and M. Petrakis,** "Factors Affecting Electricity Demand in Athens, Greece and London, UK (2009): A Comparative Assessment," Energy, Vol. 34, pp. 1855-1863, 2009.
10. **Bhattacharyya, S.C. and G.R. Timilsina. 2010.** "Modelling Energy Demand of Developing Countries: Are the Specific Features Adequately Captured?". *Energy Policy*. 38(4):1979-1990.
11. **B. Lin and J.** Jiang. 2012. "Designation and influence of household
12. increasing block electricity tariffs in China," *Energy Policy*, vol. 42, pp. 164–173,
13. **Bollerslev, Tim, Robert F. Engle and Daniel B. Nelson (1994**) "ARCH Models," Chapter 49 in Robert F.
14. **Breusch, T. S., and A. R. Pagan (1979**) "A Simple Test for Heteroskedasticity and Random Coefficient. Variation," Econometrica, 48, 1287–1294.
15. **C. Adjamagbo, P. Ngae, A. Vianou, V. Vignero** « Modélisation de la demande en énergie électrique au Togo », Revue des Energies Renouvelables Vol. 14 N°1 (2011) 67 – 83.
16. **Chang,C. C. (2010**), ‗A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China', Applied Energy, 87: 3533–3537
17. **Dickey, D.A., Fuller, W.A., (1981)** Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49, 1057–1072.
18. **Doornik J.A. et H. Hansen (1994**): « A Practical Test for Univariate and Multivariate Normality », Discussion paper, Nuffield College.
19. **DSCE :** Document de Stratégie pour la Croissance de l'Emploi.
20. **ECAM2, et ECAM3 (2001, 2008).** Deuxième et troisième Enquête Camerounaise auprès des Ménages : Institut National de la Statistique 2001 et 2008.

21. **Econoler International (2003**). Étude/Audit de la consommation et de la conservation d'énergie électrique dans le secteur public. Rapport final Décembre 2003.
22. **Engle, R.F., Granger, C.W.J., (1987**). Co-integration and error correction: representation estimation and testin. Econometrica 55, 251–276.
23. **Esseghir Asma et Haouaoui Leila. (2011)** « Croissance économique, consommation d'énergie et développement durable : l'exemple de la région méditerranéenne ».Colloque international francophone, «Le développement durable : débats et controverses », 15 et 16 décembre 2011, Université Blaise Pascal,Clermont-Ferrand.
24. **EViews.**http://www.eviews.com.
25. **Fair, Ray C. (1970).** "The Estimation of Simultaneous Equation Models with Lagged Endogenous Variables and First Order Serially Correlated Errors," Econometrica, 38, 507–516.
26. **F. Egelioglu, A. A. Mohamad, and H. Guven (2001)**, "Economic Variables and Electricity Consumption in Northern Cyprus,"Energy, Vol. 26, pp. 355-362, 2001.
27. **Filippini, M. and Pachauri, S. 2004**. "Elasticities of Electricity Demand in Urban Indian Households". *Energy Policy.* 32(3):429-436.
28. **Gaetan Lafrance (2007),**«Mathématiques et modélisation énergétique Intégration de l'éolien et prévision de demande dans un réseau électrique » Bulletin AMQ, Vol. XLVII, no3, octobre 2007 – 68 Actes du 50econgrès.
29. **Ghosh, S., 2002.** Electricity consumption and economic growth in India. Energy
30. policy 30, 125–129.
31. **Godfrey, L. G. (1988).**Specification Tests in Econometrics, Cambridge: Cambridge University Press. [22].
32. **Granger, C.W.J., (1969)**, "Investigating causal relations by econometric models and cross spectral methods", *Econometrica* 3, 424-438.
33. **G. Shi, X. Zheng, and F. Song (2012)** Estimating Elasticity for Residential Electricity Demand in China, Volume 2012, Article ID 395629, 6 pages doi:10.1100/2012/395629
34. **Hendry D.F. (1979):** « Predictive Failure and Econometric Modelling in Macro Economics: The Transactions Demand for Money". In Economic Modelling, Ormerod, P.(ed.), London: Heinemann, pp. 217–242.
35. **Issa SACKO (2004)** « Analyse Des Liens Entre Croissance Economique Et Consommation D'énergie Au Mali ». MSAS'.
36. **Kraft,J. - Kraft,A. (1978**), ‗On the relationship between energy and GNP', Journal of Energy and Development, 3: 401 -413. Lean, H.H. - Smyth,R. (2010), ‗CO2 emissions, electricity consumption and output in ASEAN', Applied Energy, 87: 1858 – 1864
37. **Masih, A.M., et Masih, R., (1998**), "A multivariate cointegrated modeling approach in testing temporal causality between energy consumption, real income and prices with an application to two Asian LDCs. *Applied Economics* 30, 1287–1298.
38. **Narayan, P.K. and Smyth, R. 2005**. "The Residential Demand for Electricity in Australia: An Application of the Bounds Testing Approach to Co-integration". *Energy Policy.* 33:467-474.
39. **Patrice Ongono** "Energy consumption and economic performance in Cameroon" MPRA Paper No. 23525, posted 27. June 2010 10:13 UTC.
40. **Payne, J.E., 2010.** A survey of the electricity consumption-growth literature. Applied Energy 87, 723–731.

41. **P. Ozoh, S. Abd-Rahman, J. Labadin, M. Apperley (2014)**A Comparative Analysis of Techniques forForecasting Electricity Consumption, *Volume 88 – No.15, February 2014.*
42. ***Samuel AMBAPOUR, Christophe MASSAMBA (*****2005*****)*** *Croissance économique et consommation d'énergie au Congo : une analyse en termes de causalité* Bureau d'Application des Méthodes Statistiques et Informatiques 2005.
43. **Xiaohua, W., Zhenmin, F., 2001.** Rural household energy consumption with the economic developmentin China: stages and characteristic indices. Energy Policy 29 (15), 1391–1397.
44. **Yoo, S.H., Lee, J.S., and Kwak, S.J. 2007.** "Estimation of Residential Electricity Demand
45. Function in Seoul by Correction for Sample Selection Bias". *Energy Policy.* 35:5702-5707.
46. **Yoo, S.-H., 2006.** Causal relationship between coal consumption and economic
47. growth in Korea. Applied Energy 83, 1181–1189.
48. **Zhou, Nan, David Fridely, Michael McNeil, Nina Zheng and Virginie Letschert, Jing Ke and Yarmina Saheb. 2011.** "Analysis of Potential Energy Saving and CO2 Emission Reduction of Home Appliances and Commercial Equipments in China." Energy Policy, 39(8, August): 4541-4550.
49. **Ziramba, E. 2008.** "The Demand for Residential Electricity in South Africa". *Energy Policy.* 36:3460–3466